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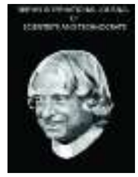

REVIEW ARTICLE

Importance of Geology in Civil Engineering

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ABSTRACT

Geology plays a vital role in modern civil engineering constructions; the above sentence is supported by historical examples in the world that influenced the modern construction methodology to be more inclusive of geology. Geology mainly consists of petrology, structural geology and geophysics. There is a reason that civil engineering students are made to study geology in their curriculum which will illustrate the various geological formations, structures and physical properties of the earth and their influence on any type of construction. This paper not only list out the various geological components that are encountered in the field but also briefly discuss the use of these components for the benefit of the construction.

Keywords: Petrology, Structural Geology, Geophysics, Geological formations, Physical properties.

1. INTRODUCTION

Geology provides a systematic knowledge of construction materials and their occurrence, formation, durability, strength, hardness and uses. Before starting any major/minor civil construction at a place, a detailed geological report which is accompanied by geological maps and sections is prepared. The detailed geological report contains types of rocks (Petrology), types of formations (geological structures) and physical properties of earth (Geophysics). Petrology is the study of rocks, where it provides rock hardness, chemical composition, strength, durability etc. Petrology is particularly important as it gives the required load bearing properties of the rock which will help in deciding the usage. Sometimes there is a possibility of rocks of acceptable compressive strength being susceptible to chemical reactions, and may not be preferred for construction in certain fields [1-4]. Structural Geology is the study of patterns that are formed below the earth like folds, faults, joints and unconformity. Structural Geology is the necessary factor at present for major construction projects. On account of the effects of these anomalies on the structures, there are few examples with negligible geological considerations which create loss to both life and property. In the recent years it has been noticed that more importance is given to the study of geological structures due to the past experiences. Geophysics is the study of physical properties and composition of the interior earth using gravity field, magnetic field and geothermal field. Modern geophysics methods that are used in civil engineering are mainly non-destructive testing. Equipment like geophones are employed to map the interiors of the earth crust by creating vibrations at a certain point and recording the same at a particular distance. Geophones use the concept of wave propagation to map the materials that may be present in the field. Geophysics is particularly important for shallow constructions where the underground amenities are not known [5-13].

2. PETROLOGY

Petrology is the study of properties such as strength, hardness, specific gravity of different rocks. Figure B1 shows the basic understanding of formation of the rocks. It can be observed that the

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formation of rocks is a cyclic phenomenon which includes cooling of magma to igneous rocks, further igneous rocks upon weathering leads to formations of sediments, after compaction and cementation of these sediments further transforms to sedimentary rocks. Due to exposure to high temperature and pressure the sedimentary rocks are converted to metamorphic rocks.

Table A1 [14-16] is the result of the tests done on all the specimens listed. Hardness of the rock is taken on the basis of Mohs scale which in turn depends on the mineral presence in the rocks; it was observed that specific gravity (sp. gr.) of the rocks vary from 2.5 to 3.5 g/cm^3 for rock forming minerals which is a bit different from ore forming minerals with sp. gr. > 3.5 g/cm^3. The data obtained below gives a rough idea of compressive strength which has been found by conducting non-destructive testing on site using rebound hammer.

3. STRUCTURAL GEOLOGY

The main components of structural geology are folds, faults and joints. This section covers some of the historical constructions that affected the future of construction market; there are a few structures that are built on these geological deformities.

- Folds are geological occurrences that are formed over a period of time due to lateral loads acting on the continental plate. Most of the intra-continental hills/mountains are basically folds, formed over a long period of time. In civil engineering the most common construction that faces problems due to folds are tunnels. One particular case has been listed below.
  - Tecolote tunnelis located at 34^{0}30’50’’ N, 119^{0}54’12.5’’W, Santa Barbara, California, USA. Tecolote tunnel is 1.8m in diameter and 9.65 km in length, bored right through the mountains, as [17] explains the presence springs and small streams that are passing through the mountains, suggesting the folded structure of the mountain. It is also noticed that during the excavation there were instances where the rocks would slide resulting in cave-ins.
- Faults are discontinuities in the continental plate. Fault characteristics contain strike, dip, hanging wall and foot wall. History teaches us that there were many instances when civil engineering constructions have been constructed faulty. Three cases are listed below along with the repercussions of the same.
  - Three gorges dam – located at 30^{0}49’23’’ N, 111^{0}00’12’’ E in SandoupingYilling, China. This dam happens to be constructed on an inactive fault; the presence of reservoir tended to increase the weight on the fault, causing massive land-slides in the area. On July 13, 2003; 24 million cubic meters of rock and earth slid in the Qinggan River, completely blocking its flow, capsizing 22 boats and destroying four factories, 300 homes, and more than 67 hectares of farmland. Official reports say that 14 people were killed and 10 more were listed as missing [18]. In 2007, 31 people died when a landslide crushed a bus in Hubei province [19]. In the fall of 2007, officials and experts admitted that the three Gorges dam project had caused more frequent landslides [20, 21]. Tan Qiwei, Vice Mayor of Chongqing, suggested in Wuhan that the shore of the reservoir had collapsed in 91 places and a total of 36 km of shoreline had caved in.
  - Nagarjunasagar dam – located at 16^{0}34’32’’ N, 79^{0}18’42’’E in Nalgonda District of Telanganain, India. This dam is constructed on a fault zone located with a strike direction of N40^{0}E, S40^{0}W and dip angle of 28^0. After several excavations it was found out that the hanging wall mostly comprised of Granite-Gneiss combination, and were highly fractured and formation of joints were observed, whereas the footwall was made up of massive Granite-Gneiss without the above deformities. [22] mentioned the occurrences of seismic activity in the locality but discards the probability of an artificial earthquake. From the data, a magnitude of 3.2 was observed in the vicinity of the dam. It was reported that the earthquake was neither due to the construction reservoir nor the dam but it was due to natural seismic activity in Kalawa and Atmakur faults. This can be taken as an example of civil structure constructed on a fault but is still stable to this date.
  - Koyna dam – located at 17^{0}24’06’’ N, 73^{0}45’08’’ E in Koynanagar, Maharashtra, India. A lot of inspection has been done in relating to the same conclusion that the earthquake of 10th September 1967 was an

induced earthquake caused by the slippage of the fault located in the vicinity of the dam [23]. The sudden occurrence of earthquake in an inactive fault raised many questions regarding the construction procedures followed in India. [24] suggested that earthquake may be a natural occurrence rather than an induced one, but the absence of any earthquake previously in the region points in the direction to believe that this is a seismically inactive zone, thus concluding that the Koyna earthquake was an induced one. To elaborate the above theory, it collected the earthquake data of Koyna dam from its first occurrence i.e. 10th September 1967 till 20th September 1980. Over all these years, it has been noticed that during the years 1967 to 1976 the earthquakes were shallow earthquakes ranging from 4m to 14.5m depth with magnitudes varying from 4.1 to 6.2. In the year 1980 earthquake, the depth of focus was 33m and the tremors were felt thrice in the same month with magnitudes of 5.2, 5.3 and 5.4 respectively. The above data shows that due to the presence of fault in a construction area, even if inactive previously, can be forced artificially to result in artificial earthquake.

- Joints are formed in rocks and mostly are fractures caused by weathering agents like water, wind, temperature etc. The only noticeable change due to joints is increment in secondary porosity and permeability. There are many grouting procedures followed to increase the strength of the rock [25-32].

4. GEOPHYSICS

The importance of Geophysics is observable in the sub-soil exploration where foundations are laid. The presence of fault zones or fold zones can be located with the methodologies provided by geophysics. The methods mentioned below are used before the commencement of any major project at present to locate the presence of geological structures underground. [33-39] suggested that the main principles of Geophysics are the concepts of non-homogeneity in the earth surface, and their reaction to the magnetic, electrical, radioactivity and thermal exposure. In this paper two methods are discussed and are used extensively throughout the world; they are: so- named Seismic Refraction Method (SRM) and Electricity Resistivity Method (ERM) as illustrated in Table A2.

[40] used the electrical resistivity method to map the profile of road subsurface using ABEM Terrameter SAS4000 LUND imaging system, which uses two current electrodes, where direct current is applied into the ground and using two potential electrodes, the potential drop was recorded. By using the above method, the thickness of the surface course, base course, sub-base course and sub-grade course is found and is compared with Dynamic Cone Method (DCM). It was found that the data recorded using DCM and ERM had very negligible difference. Some other field examples are: ERM that was used in Bokaro steel plant in Bihar to delineate bedrock configuration in detail at plant site and the one used for an atomic power plant in Andhra Pradesh to determine the nature and position of quartzite in the area and to estimate the thickness of quartzite.

On the similar lines, seismic refraction method is also conducted with the difference that in ERM, electricity is used but in SRM seismic vibrations are recorded at a distance from the main instrument. [41] used the above methodology to study the sub-surface of a bituminous road. The study shows that SRM is equivalent in accuracy to the bore hole drilling test. But when deep strata profiling is in question, SRM is not preferred. Due to the vibration travelling vertically downward, it is not easy to record. Some of the other examples where SRM has been extensively used are Beas-Sutlej link project of Himachal Pradesh to determine the thickness of overlying alluvial deposits; and, another example is Kopilihydel project, to detect faults clay beds cavernous limestone.

5. CONCLUSION

This review provides us with a very important realization that due to poor geological studies, there were many instances in civil engineering where the damage has been incurred not just on the properties but on lives too. Studies on petrology gives an overview of the strength properties of the rocks which helps a civil engineer decide where and how a rock has to be used in constructions; similarly the study of geological structures like faults helps us understand the behaviour of faults under static loading condition. Many examples in Structural Geology section of this Paper are inspired from dams where the static

loading of reservoir has finally resulted in movement in faults, which further resulted in an induced earthquake. If proper geological experiments/study would have been carried out in the locations, the location of dams would have been altered saving loss of properties and lives. The study of geology and geophysics should be made mandatory, so that natural calamities could be avoided to a great extent.

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APPENDIX A

Table A1.Physical properties of rocks

Name of rock	Physical Properties of Rocks					
	Mineral present	**Sp. Gr.**	**ρ (Kg/m^3)**	**Compressive strength (Kg/cm^2)**	**Hardness (Mohs scale)**	**Uses**
Granite (igneous rock)	Quartz & feldspar	2.60-2.80	2500-2650	370-3790	7	Foundation rock, building stone, road metal etc.
Basalt (igneous rock)	Augite, calcic plagioclase and iron oxides	2.80-3.00	2800-3000	2671	6	Building stones, road metal, aggregate in cement concrete, suitable for tunnelling, ballast for railway tracks etc.
Gabbro (igneous rock)	Labradorite, plagioclase feldspar and augite (type of pyroxene)	2.80	2800	460-4700	5-6.5	Ornamental stone, paving stone, graveyard headstone
Syenite (igneous rock)	Feldspar And Quartz	2.60-2.70	2600-2700	1000-3440	5.5-6	Foundation rock, building stone, road metal etc.
Pegmatite (igneous rock)	Alkali feldspar, quartz and mica	2.60-2.63	2600-2630	1820	2.1	Unsuitable for engineering constructions
Siliceous Sandstone (sedimentary rock)	Quartz	2.20-2.80	2200-2800	110-2520	6-7	Building stone, railways, tunnelling etc.
Shale (sedimentary rock)	Montmorillonite, Kaolinite ,illite	2.00-2.40	2000-2400	313	3	Rarely building stone, cement aggregates art clay products
Lime stone (sedimentary rock)	Calcite and aragonite	2.30-2.70	2300-2700	1172	3-4	Road metal railway ballast, construction material, flooring Limestone is undesirable for foundation
Dolomite (sedimentary rock)	Calcite	2.80-2.90	2800-2900	1427	3.5-4	Construction aggregate, cement manufacture, metallurgical flux
Laterite (sedimentary rock)	Quartz, zircon, iron, tinaluminum, manganese, and oxides of titanium	2.65-2.67	2650-2670	-	2	Cobblestones, for Road Aggregate, Landscaping, Road stone Decorative Aggregates Flooring, Interior Decoration

Marble (Metamorphic rock)	Calcite	2.86-2.87	2400-2700	310-2620	3-4	Building stone(temples) Face work, flooring wall panels
Quartzite (Metamorphic rock)	Quartz	2.60-2.80	2600-2800	260-3200	6-7	Manufacture of silica bricks Railway ballast Concrete aggregate Construction aggregate
Gneiss (Metamorphic rock)	Feldspar and quartz	2.50-2.70	2600-2900	810-3270	7	Facing stone, Building stone, Facing stone Flooring, road metal, concrete aggregates suitable for tunneling
Schist (Metamorphic rock)	Hornblende, actinolite and tremolite	2.50-2.90	2500-2900	-	3.5-4.0	Unsuitable for construction
Slate (Metamorphic rock)	Sericite and quartz	2.65-2.80	2700-2800	600-3130	3-4	Roofing, Flooring, Shelves, Undesirable for foundation

Table A2.Geophysical methods

Method	**Geophysical methods and application in Civil Engineering**	
	Physical property measured	**Applications**
Seismic Refraction Method (SRM)	Elastic property	Shallow seismic procedures like seismic refraction methods involve equipment's that measure the travelling time of tremors caused artificially.
Electrical Reistivity Method (ERM)	Electrical resistivity	This method is quite useful in locating the soft rock formations in the top strata. Different rocks have varied electricity resistance.Using that a map representing rock at different depths can be formed.

APPENDIX B

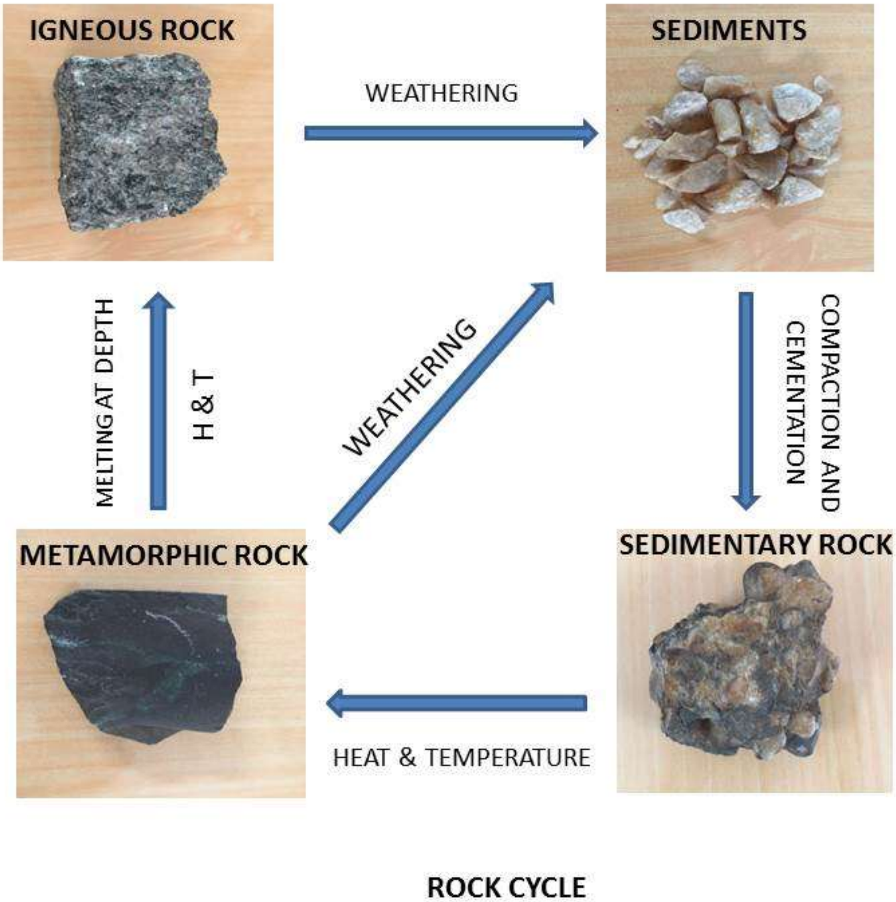

Figure B1.Rock cycle